1983

Differences of selected performance parameters of dominant and nondominant legs of soccer players

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DIFFERENCES OF SELECTED PERFORMANCE PARAMETERS OF DOMINANT AND NONDOMINANT LEGS OF SOCCER PLAYERS

A Thesis

Presented to

the Faculty of the Graduate School

University of the Pacific

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

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June 1983

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DEDICATION

This paper is dedicated to the block from which this chip came, my father, Edward R. Spaulding. It was his love and active involvement in sports that has helped to make it possible for this task to be completed. Through his support and guidance for these many years, I have learned to appreciate the rewards of hard work and the satisfaction in doing my best. In the words of my father, "Winning is never easy." He has shown me when success comes, it means a great deal more to those who have had to work for it.

ACKNOWLEDGEMENTS

I would like to thank the following people for their time, interest and help in completing this project.

To the Men's 1980 Varsity Soccer Team for their dedication and hard work during the experiment.

To Jerry Solberg, R.P.T., who donated his time, knowledge, and the use of S.T.A.R. Clinic facilities.

T. Dr. S. T. Stubbs who helped in the completion of this paper.

To Dr. J. Conner Sutton who guided the author through the never ending tasks in the completion of this project.

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Chapter 1

INTRODUCTION

John Jesse (42:68) states that "Sports predispose an athlete to unilateral and imbalanced muscular development. These are activities leading to the considerable overdevelopment of muscles on one side of the joint or body." According to Jesse, the more refined an athlete becomes in a sport which requires bilateralability, increased emphasis should be placed on the individual to create an absolute muscle balance. From early childhood through old age a muscular imbalance of the muscles surrounding the body joints exists. This imbalance may increase as an individual uses his preferred side in daily exercises, or the imbalance may decrease if the individual attempts to reduce the ratio of imbalance. In either instance there never can be an absolute muscle balance in the body.

Several variables affect the methods in which an individual trains to achieve this state of absolute muscle balance. Speed, strength, and power (6, 7, 14, 18, 50) all have an effect on the results of any training technique. The specificity of training becomes an important factor. Matching the speed of training to the speed of performance becomes essential for improvement.

According to Grimby and associates (38) training at fast limb motion speeds, an individual may increase his functional strength more effectively. This has been reinforced in various other studies (10, 30, 51, 88, 89).

Contrary to those results, Rasch (75:328-33) concluded "the speed of the movement has little relationship to strength and the two are reasonably separate entities." According to Rasch, strength and power are related and separate from speed. The question of the relationship between speed, strength, and power creates disagreement. Some investigators have found the two variables to be related (10, 51, 88, 89) while other researchers find the relationship to be nonexistent (5, 75).

Hutto (41) found through his study that when strength and velocity factors (speed) work together during physical activity, they act as a single factor, that factor being defined as athletic power.

Costill and his associates (19), however, found power to be related to dynamic strength, while velocity was related to speed, but only moderately related to explosive leg strength. Costill concluded that speed may be the primary element of power.

Due to the differing results and conclusions, further investigation was done by this investigator in order to examine the possible differences in leg strength between the dominant and nondominant legs of soccer players, and measure the possible differences in shot velocity after a resistance training program.

Statement of the Problem

The main problem of this study was to determine if a significant strength difference existed between the mirror muscles of six muscle groups in the dominant and nondominant legs of University of the Pacific male soccer players at differing contraction speeds as measured by the

Cybex II Isokinetic Dynometer. In addition to the main problem, fourteen subproblems were also established.

S_1. The first subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the dominant leg following an eight week training program.

S_2. The second subproblem was to determine if a significant change occurred in strength in any of the six muscle groups of the nondominant leg following an eight week training program.

S_3. The third subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the dominant leg after a ten day rest period following the conclusion of the training program.

S_4. The fourth subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the nondominant leg after the ten day rest period following the conclusion of the training program.

S_5. The fifth subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the dominant leg when comparing the test scores taken at the end of the eight week training period to the test scores taken after the ten day rest period.

S_6. The sixth subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the nondominant leg when comparing the test scores taken at the end of the eight week training period to the test scores taken after the ten day rest period.

S_7. The seventh subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the dominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program.

S_8. The eighth subproblem was to determine if there would be a significant change in strength in any of the six muscle groups of the nondominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program.

S_9. The ninth subproblem was to determine if there would be a significant change in the velocity of a soccer ball kicked with the dominant leg following an eight week training program.

S_{10}. The tenth subproblem was to determine if there would be a significant change in the velocity of a soccer ball kicked with the nondominant leg following an eight week training program.

S_{11}. The eleventh subproblem was to determine if there would be a significant difference in ball velocity between the experiemental group and the control group when kicking a soccer ball with the dominant leg during the pre-test.

S_{12}. The twelfth subproblem was to determine if there would be a significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the dominant leg following an eight week resistance training program.

S_{13}. The thirteenth subproblem was to determine if there would be a significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the nondominant leg during the pre-test.

S_{14}. The fourteenth subproblem was to determine if there would be a significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the non-dominant leg following an eight week resistance training program.

The Importance of the Study

Increasing numbers of studies are being done dealing with the effects of weight training and physical performance in relation to athletic ability. When the concept of resistance training became an important element of an athletic program, many studies were done in order to establish a program that would help athletes to improve their physical performance (2, 7, 15, 36, 51, 85).

Initially, there was a great deal of discussion as to the advantages of isometric or isotonic weight training (3, 4, 5, 6). There were both advantages and disadvantages found for both methods of training, but it was found that the isotonic weight training programs utilized specificity for the training technique. Strength gain through the full range of motion, as contrasted by the isometric training programs where the strength gain was achieved at different positions, fulfilled the principle of specificity of training.

More recently istonic training methods have been tested against isokinetic training methods (56, 69, 70). Even though both methods of training have been found to increase strength, it is suspected that unless the gains in strength are specific to the exercise and method of training, the increase in the muscle strength will not enhance an athlete's ability (70). In other words, it is important that the method of training being used be adapted in such a way that it meets the specific training needs of the individual athlete for a specific movement.

The review of the literature showed the importance toward the specificity of training but little work was found to deal with the unilateral development and imbalance of muscular development with regard to a sport which requires ambifunction. In a study done by Bailey (1:8) it was found that in a sample size of 93 high school football players, "one out of four had an imbalance of 10 percent or more between power scores of the quadriceps group at both knees, and one out of three had 10 percent or more difference between the hamstring groups." Bailey also found a need to establish exercises to "balance" knee strength and power, since such imbalances are a major factor in severe knee injuries. Because of this information it becomes apparent that decreasing the imbalance of muscular development also decreases the probability of injury, and therefore plays an important role in an athlete's training.

Statement of the Hypotheses

The following hypotheses stated in null form for statistical purposes were developed. The main hypothesis was that there would be no significant strength difference between the mirror muscles of six muscle groups in the dominant and nondominant legs of University of the Pacific male soccer players at differing contraction speeds as measured by the Cybex II Isokinetic Dynometer. In addition the following hypotheses were established for the subproblems of the study.

$\underline{H_1}$. There would be no significant change in the strength in any of six muscle groups of the dominant leg following an eight week training program.

$\underline{H_2}$. There would be no significant change in the strength in any of six muscle groups of the nondominant leg following an eight week training program.

$\underline{H_3}$. There would be no significant change in strength in any of the six muscle groups of the dominant leg after the ten day rest period that follows the conclusion of the eight week training program.

$\underline{H_4}$. There would be no significant change in strength in any of the six muscle groups of the nondominant leg after the ten day rest period that follows the conclusion of the eight week training program.

$\underline{H_5}$. There would be no significant change in strength in any of the six muscle groups of the dominant leg when comparing the test scores taken at the end of the eight week training period to the test scores taken after the ten day rest period.

$\underline{H_6}$. There would be no significant change in strength in any of the six muscle groups of the nondominant leg when comparing the test scores taken at the end of the eight week training period to the test scores taken after the ten day rest period.

$\underline{H_7}$. There would be no significant change in strength in any of the six muscle groups of the dominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program.

$\underline{H_8}$. There would be no significant change in strength in any of the six muscle groups of the nondominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program.

$\underline{H_9}$. There would be no significant change in the velocity of a soccer ball kicked with the dominant leg following an eight week training program.

$\underline{H_{10}}$. There would be no significant change in the velocity of a soccer ball kicked with the nondominant leg following an eight week training program.

$\underline{H_{11}}$. There would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the dominant leg during the pre-test.

$\underline{H_{12}}$. There would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the dominant leg when comparing the pre-test to the post-test.

$\underline{H_{13}}$. There would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the nondominant leg during the pre-test.

$\underline{H_{14}}$. There would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the nondominant leg when comparing the pre-test to the post-test.

Statement of Assumptions

This study was based on the following assumptions:

1. It was assumed the testing yielded true, maximal, voluntary muscle contractions throughout the experiment.

2. It was assumed the control group performed as requested and did not participate in a resistance training program.

3. It was assumed that, as requested, during the ten day rest period no one participated in any type of resistance training program.

Statement of Delimitations

This study was delimited as follows:

1. The sample consisted of members of the 1980 men's varsity soccer team at the University of the Pacific.

2. Those individuals selected for the control group were requested not to participate in any resistance training program.

8. The training period was delimited to eight (8) weeks.

Definition of Terms

Pertinent terms were defined in order to help the reader understand their meaning.

Dominant Leg (preferred). Dominant leg is the leg the indivudal used the majority of the time for kicking. In the case of a person who was ambipedal, the dominant arm was determined and the leg on that side of the body was classified as dominant.

Nondominant Leg (Nonpreferred). Nondominant leg is the leg the individual used the majority of the time for supporting the body while in kicking stance. In the case of a person who was ambipedal the nondominant arm was determined, and the leg on that side of the body was classified as nondominant.

Plant Leg. Plant leg is the leg that was used for supporting the body while kicking.

Kicking Leg. Kicking leg is the leg that was used for kicking in a particular exercise or trial.

Strength. Strength is the capacity to exert muscular force against resistance (87).

Power. Power is the rate of work or work per unit of time (8).

Velocity. Velocity is the amount of displacement per unit of time (the rate of displacement) (87).

Isotonic Contraction. Isotonic contraction is a contraction in which tension is exerted and the muscle changes in length (87).

Isometric Contraction. Isometric contraction is a contraction without any appreciable change in length of the muscle (87).

Isokinetic Exercise. Isokinetic exercise allows maximal resistance throughout a range of joint motion (87).

Overload. The overload principle occurs when a muscle works at a rate greater than accustomed and must adapt to the stress placed upon it (27).

Muscle Endurance. Muscle endurance is the ability of the same muscle group to make repeated contractions against a defined resistance (27).

Ambipedal. Ambipedal is the ability of an individual to use either foot equally well.

Bilateral. Bilateral development is the development of both sides of the body at an equal rate.

Mirror Muscle Groups. Mirror muscle groups refers to the same muscle group on the opposite leg. Ex.: right quadricp - left quadricep.

Antagonistic Muscle Groups. Antagonistic muscle groups refers to the muscle groups which are involved in reciprocal innervation.

Reciprocal Innervation. Reciprocal innervation relaxes the antagonistic muscle as the agonistic is commanded to contract.

Chapter 2

REVIEW OF THE RELATED LITERATURE

The concept of muscle strengthening and weight training has been in existence for decades. Both athletes and nonathletes alike have been trying to enhance their performance with regard to physical activity. Even though the methods for reaching this goal have changed over the past several years, there are still differing opinions as to the best method for training to reach a specific goal. The review of the related literature revealed several different methods by which individuals can increase muscle power, strength, and speed. Numerous studies have been done in the fields of isometric, isotonic and isokinetic weight training programs. These three different weight training techniques have been compared by numerous investigators to determine which procedure is the most beneficial for a specific goal. In this chapter the above mentioned types of weight training programs will be discussed and compared as a result of various studies done by researchers.

According to Mathews and Fox (52) there are four types of muscular contraction. They are: (1) an isotonic contraction which produces the same amount of tension while shortening as it overcomes a given resistance; (2) an isometric contraction where tension is developed but there is no change in external length of the muscle; (3) an eccentric contraction in which the muscle lengthens during the contraction; and (4) an isokinetic contraction in which the tension developed by the muscle as it shortens is maximal at all joint angles over the full range of motion.

For more than thirty years there has been controversy over the advantages and disadvantages of the different types of weight training. Initially isometric weight training was compared to isotonic weight training and more recently the concept of isokinetic weight training has increased in popularity. All three techniques have both advantages and disadvantages with regard to accessibility, use, and the functional benefits relative to the strength gain process.

Isometric Exercise

An isometric contraction is a contraction without any appreciable change in length of the muscle. The muscle is unable to shorten because of the magnitude of the resistance (87). The effort exerted causes considerable pressure against the resisting force causing the firing of the motor units within the body. The length of the muscle remains constant throughout the contraction even though the tension of the muscle increases greatly during the contraction. An isometric contraction works to conteract the stretch of the muscle. The two forces--contraction and stretching--applied in opposite directions create the tension.

It has been found in various studies that when using the isometric method of weight training, training statically for six to eight seconds at several different positions causes an increase in the muscle strength (3, 6, 7). In 1953 Hettinger and Muller (39) published their work on isometric training and their findings showed that a maximum training effect could be obtained from one daily, six second, isometric contraction against two-thirds of an individual's maximal contraction strength. This concept has since been reinforced in more recent studies (3, 6, 74).

The chief advantage in using the isometric method of training is time. Great savings in time are possible if only one contraction per day is used. Also the equipment needed and used is readily available to exercise large groups.

Isotonic Exercise

An isotonic contraction is a contraction in which the tension remains constant as the muscle shortens. The muscle fibers shorten and lengthen throughout the movement. This is reflected in the term iso, meaning constant, and tono, meaning tension (87).

DeLorne and Watkins (26) presented a protocol for load resisting exercises. They found low repetition and high resistance exercises produce power whereas high repetition and low resistance exercises result in endurance. Through their investigations, DeLorne and Watkins found that an increase in strength will occur with 60 percent of the maximum weight. It was found that 3 sets of 10 RM (repetitions maximum) would increase an individual's strength. An example of this procedure would be as follows: Set number 1 = 1/2 RM; set number 2 = 3/4 RM; set number 3 = 10 RM. As the strength increases, the weight should be adjusted accordingly.

Zinovieff (96) later developed what is now known as the "Oxford Technique" in isotonic weight training. Following an initial warm-up, 10 sets of 10 contractions are performed. Upon the completion of each set, the weight is decreased. This is done in order to continue exerting at a maximum capacity throughout the entire workout session. Zinovieff concluded that 6 RM for 3 sets, 3 times weekly, was sufficient to cause strength gains.

According to Glein, Nicholas and Webb (37) isotonic testing measures dynamic strength. The greatest advantage in using the isotonic method of training is that strength gains are specific to the angle at which the resistance is encountered. Therefore, isotonic exercise can be designed to work the entire range of motion in one contraction. When comparing the isotonic to the isometric method, several contractions would be needed at different angles to work the full range of the motion. The inherent limitation in this method is that strength is measured at the weakest point in the range of motion.

Recently there have been numerous studies done experimenting with isokinetic resistance training programs. Comparisons have been made with isometric, isotonic, and isokinetic weight training programs. According to Wilson (91:39)

> The major problem with isometrics and isotonics is maintaining a maximal muscle load throughout the full range of motion. Isometrics do not allow the full range of motion, but overload the muscles. Isotonics use a full range of motion but the constant weight does not allow the mechanical advantage differences. The ideal system would combine the positive and eliminate the negative features.

When using isokinetic exercise the muscles are loaded maximally through the full range of the movement. Isokinetic exercise permits the optimum strength-building stimulus throughout the entire movement (10).

Isokinetic Exercise

In 1967 James J. Perrine (62:41-4), a bioengineering consultant, introduced a new type of resistance exercise called Isokinetic Exercise. "A special training device attached to the limb controls motion at a predetermined speed, and allows maximal resistance instead of increased acceleration throughout a range of joint motion." No matter how much force is applied, the speed of the lever arm will not accelerate, allowing maximal resistance to be applied throughout the movement. During isotonic exercise, the speed of the movement is controlled by the individual, and the load remains constant throughout the range of the motion. This makes it possible for the individual to control the speed of the movement, and the force of the movement can overcome the weak joint angles. In isokinetic exercise, the resistance from the machine matches the individual's capability throughout the range of motion. If maximal muscular force is applied throughout the movement, the lever arm remains at its preset, constant, motor driven speed.

In 1969 Perrine (67) patented the first isokinetic strength testing device. The following year Lumex Inc. bought the patent and license rights.

Comparisons of Istonic and Isokinetic Exercises

Tests to compare isotonic exercises to isokinetic exercises are possible as both methods exercise the muscles through a full range of motion. Isometric exercises do not exhibit a full range of motion and therefore make comparisons difficult, because limb speed becomes a factor with regard to increases in strength.

According to Pipes and Wilmore (69:262-74), "The superiority of isokinetics is probably due to the nature of the isokinetic contraction, i.e., maximal resistance through the total range of motion." Pipes and Whitmore (70) also examined the differences in low speed training and high speed training when using isokinetics. They found the gains in strength for the isokinetic high speed group, in most cases, greater than the isokinetic low speed group. They concluded that isokinetic high speed training appeared to be the preferred procedure for maximum change. Their results have since been reinforced by other research studies (1, 10, 37, 56, 77).

It is apparent that speed and power, as they are related to strength, play an important role in physical activities. Performance depends on several different things. Explosive power, speed of the movement, and anaerobic muscle endurance all bring about increased performance.

Strength

Strength, which is defined by Rarick (74:333) as the "maximum tension that a muscle can produce," results from working the muscle against resistance greater than that to which it is accustomed. An increase of a whole muscle's contractile strength can be affected by: (1) increasing the frequency of stimulation of the active motor units and (2) by mobilizing an increasing number of motor units.

When a muslce or muscle group is required to work at higher intensity than that to which it is accustomed, hypertrophy occurs. This phenomena is also known as the overload principle.

> Hypertrophy of individual muscle fibers is attributable to one or more of the following changes:
> 1) increased number of myofibrils per muscle fiber.
> 2) increased total amount of protein, particularly in the myosin filament.

3) increased capillary density per fiber.
4) increased amounts (and strength) of connective tendinous and ligamentous tissues.
5) increased number of fibers, resulting from longitudinal fiber splitting.
6) biomechanical changes leading to increases in ATP, PC, glycogen, mitochondrion and various enzymes (52).

Hypertrophy, strength, and endurance of a muscle will increase only when the muscle performs at its maximal strength and endurance capacity when the muscle performs for a given period of time. The work loads must be above those normally encountered.

Previous investigators have indicated that training increases the number of fibers recruited and/or brings about a more synchronous firing of motor units (49, 76). This suggests that in order to improve performance, an athlete should train at speeds approximately the same, or exceeding those used during the actual event. Strength and speed are related with regard to performance. deVries (27) reported that strength gains from heavy resistance exercise are limited to velocities at or below those used in training. Therefore training at increased speeds becomes essential for improving velocities during resistance training. The fast twitch fibers must be utilized in order to adapt to the specific function needed.

In studies done by Lesmes, Costill, Coyte, and Fink (50), and Moffroid and Whipple (56), it was shown that significant gains in strength only occurred at the velocity contraction at which the training occurred. Significant gains in strength could not be demonstrated when the velocity of contraction was greater than the speed at which the training occurred.

Speed

Speed is defined by Edgerton (29:49-8) as

> the length of time it takes a motor unit to reach a peak tension when it is given a maximal shock. The shortest time to peak tension occurs in the motor units that also have the largest motoneuronal cell body, axon, and muscle fibers.

To improve speed, continuous high speed repetitions of desired movement with a high intensity must be performed. Improving strength is the most important factor in increasing speed. Also neuromuscular coordination plays an important role in increasing speed (27).

Power

Power, which is the rate of work or work per unit of time, implies a combination of speed and strength to develop fast explosive movements against resistance (31). Power suggests the ability to apply maximum force in the shortest length of time. The power of a muscle is related to the number of muscle fibers working. As the load of the muscle increases, so does the number of motor units required to operate the muscle.

In 1964 Kaneko and Ikai (45) did research using electromyograms. They found that subjects with high power showed more concentrated nerve impulses to the muscle at the onset of the movement, resulting in high, dynamic force. Riley (77) discovered that it is possible to exert forces of graded strengths ranging from a barely perceptive contraction, to the most vigorous type of contraction, depending on the number of motor units stimulated.

Fundamentally a motor unit is made up of a single muscle nerve and all muscle fibers innervated by it. The ratio of muscle fibers innervated by a single motor nerve is not determined by the size of the muscle, but rather by the precision, accuracy, and coordination of the movement (52). Differences in muscle fiber composition in skeletal muscles of athletes have led to speculations as to the biological importance of the fast twitch and slow twitch muscle fibers in man (84).

For many years muscle fibers have been classified in two groups: red fibers, which are considered to have slow contractual properties, and white fibers, which are considered to be differentiated for speed of contraction (27). According to Mathews and Fox (52), the majority of our muscles contained an approximately equal mixture of red and white fibers. Individual differences in percentage composition of red and white fibers in any given muscle are largely a matter of genetics.

More recently researchers have come to an agreement that muscle fiber types should be classified in three different categories. deVries (28) has reported there are two subtypes of fast twitch fibers. These fibers respond differently to training. The training can bring about considerable improvement in both aerobic capacity and glycogen content of the muscle.

Fiber type composition for athletes becomes apparent when different types of training programs are examined. Individuals with slow twitch oxidative fibers would be able to compete in endurance events, whereas individuals with a high percentage of fast twitch fibers would be successful in power and sprint events.

In studies of human muscle using only two categories of fibers, slow twitch (ST) and fast twitch (FT), there is agreement that these two categories do not change their relative proportions as the result of training; only their size and oxidative capacities improve (38). However, recent work using the newest classification of three muscle types suggests that changes within the FT fibers are the important responses to training. Thus research suggests that humans can adapt to different muscular activities by way of a shift from fast twitch, glycolytic, to fast twitch oxidative, glycolytic fibers in response to distance running, and from fast twitch, oxidative, glycolytic to fast twitch, glycolytic muscles in response to weight training (28).

According to Berger (7), fast twitch fibers are found in greater concentration in athletes whose events demand high muscle strength and power. In addition to this, Thurstensson (84) found that the proportion of fast twitch fibers is related to torque produced at high motion velocity. Torque, as stated by Lesmes and associates (50), is an adaptation of neurological control of muscle fiber recruitment. Increases in torque output were due to possible neuromuscular adaptations. Previous studies have shown that training increases the number of fibers recruited and/or brings about a more synchronous firing of motor units (20). Therefore torque, and the adaptation of neurological control, plays an important role in the development of high motion velocity.

Endurance

Endurance is an important aspect of muscular fatigue. Fatigue occurs when the muscle fibers lose their ability to contract. Each motor unit is able to contribute less force to the contraction, and consequently increased numbers of motor units must be recruited to maintain the same level of tension (28).

Edgerton (29:49-8) found that "a gradual and consistent decline in impulse/sec. of all motor units that were recruited at the onset of the maximal effort occurred with a prolonged muscular effort." Endurance capabilities with regard to motor unit recruitment seem to increase in the muscles as their ability to withstand fatigue improves.

Rarick (73) states that there are two types of endurance which affect muscle function. They are: (1) aerobic endurance and (2) anaerobic endurance. Aerobic endurance is the general ability to withstand fatigue of the entire organism in the presence of a sufficient supply of oxygen over a prolonged period. Anaerobic endurance is the general ability to withstand fatigue of the entire organism when oxygen is in insufficient supply.

Soccer Fitness

Ability in soccer can be directly related to physical fitness attributes. According to Cramer (24) there are basically three different components of fitness. They are: (1) endurance and stamina; (2) quickness and speed; and (3) strength and power.

Endurance can be broken down into general endurance and local muscle endurance. General endurance refers to the ability of a player to withstand the varied intensity of a competition match of some length. This ability in soccer depends primarily on a properly trained circulatory system. Local muscle endurance is improved through anaerobic training.

Speed in soccer is desired in several aspects of the game. Initially a player must have a quick start. The first several steps are much more important than the fifth or sixth step. A player must also be quick and pliant in his motion and angle. Soccer requires many directional changes, so if the player is not agile enough, these changes cannot be made quickly enough.

Strength and power involve the overloading of muscle groups when training. When impulses during training are stronger than those required in competition, reserve strength is built up which can lead to better performance.

Soccer, like many sports, requires the development of both sides of the body for improved performance. In soccer a player must be able to use either foot equally well. According to Jesse (42:68), one of the problems faced by athletes is the imbalance of muscular development.

> The muscles of the right side of the body (the dominant or preferred side) are better developed than those of the left side (the non-dominant or non-preferred). Sports predispose an athlete to unilateral and imbalanced muscular development. These are activities leading to a considerable overdevelopment of muscles on one side of the joint or body.

Jesse also states there can never be an absolute muscle balance in the body. The muscle imbalance exists from childhood through old age. The goal of conditioning should be to reduce the ratio of the imbalance to as small a ratio as possible.

There is little other definitive information in the literature dealing with muscular imbalance in sports participants. Jesse's statements have influenced the author's thoughts in that direction, but because of the dearth of research, the hypotheses developed for this study were presented in the null form.

Analysis of the Soccer Kick

Roberts and Metcalfe (78) presented their findings of the mechanical analysis of the soccer kick in 1967. Using films and a timer, the soccer kick was analyzed using a frame by frame breakdown.

The kicking foot, shortly after it is lifted from the ground, moves laterally as well as forward in the direction of the ball. This movement of the leg increases the usable range of pelvic rotation. Hip flexion, which increases foot speed in the sagital plane, follows the pelvic rotation. The pelvic and hip action begin to move the foot laterally and downward, but knee flexion counteracts the early effect of the pelvic and hip action both on direction and rate of motion of the foot. The angular motion of the kicking leg in the sagital plane is a combination of rotation of the thigh and action at the knee joint.

As the nonkicking heel contacts the ground, knee flexion is in opposition to forward thigh rotation so that there is little rotation of the leg. As the knee flexion of the kicking leg slows the leg begins to rotate due to hip flexion. When knee extension begins and accelerates, the leg gains speed. At the same time the thigh begins to slow down and almost stop. Knee extension which does not start until the thigh is past its perpendicular is the main contributor to the speed of the leg at and through the contact of the foot and the ball. The foot follows the leg and only slight ankle adjustments occur.

In short, it was found that as in running, rotation of the pelvis precedes joint actions in the swinging limb (kicking leg). Hip flexion follows, creating an acceleration of the thigh. Knee extension comes in last adding the final speed to the kicking foot.

After examining and analyzing the soccer kick, the following muscle groups were selected for testing during this study:

1. The quadricep muscle group at speeds of 60°/second, 180°/second and 210°/second.

2. The hamstring muscle group at speeds of 60^{0}/second, 180^{0}/second and 210^{0}/second.

3. Hip Flexion

4. Hip Extension

5. Leg Adduction

6. Leg Abduction

(See Appendix A for muscle groups used during the different movements.)

Chapter 3

RESEARCH METHODOLOGY

The purpose of this study was to determine if a significant strength difference existed between the mirror muscles of six muscle groups in the dominant and nondominant legs of University of the Pacific male soccer players at differing contraction speeds as measured by the Cybex II Isokinetic Dynometer. Numerous subproblems were established in order to test various factors important to the study.

The Sources of the Data

The sample was made up of eighteen male varsity soccer players from the 1980 University of the Pacific Soccer Team. Those chosen for the study needed to fulfill the requirement of having played competitive soccer for a minimum of four years. This was done to ensure at least a minimum competency level. The data-producing sample contained players whose years of experience ranged from four to sixteen years. The ages of the sample group ranged from eighteen to twenty-three.

Data Collecting Instrument

The Cybex II Isokinetic Dynometer (Lumex, Inc., Bay Shore, New York) (25) was used for gathering the data related to testing the strength in foot pounds of the muscle groups.

The angular velocity of the dynometer was set at 60 degrees/second, 180 degrees/second, and 210 degrees/second for the knee extension and flexion. The angular velocity was set at 30 degrees/second for the flexion and extension of the hip, and adduction and abduction of the leg.

According to the Cybex Company (25) and Jerry Solberg R.P.T. (81), the different settings of 60, 180, and 210 represent actual movement speeds which can be simulated on the machine. A setting of 60 represents the approximate limb speed produced as a person walks. A setting of 180 represents the approximate limb speed as a person jogging. A setting of 210 represents the approximate limb speed as a person sprinting. According to Solberg (81), "The setting of 210 yields a more realistic reading for an athlete."

The setting of 30 was used for exercising and testing flexion, extension, adduction and abduction due to the fact that the torque from the legs on the machine would have damaged the Cybex II at a faster setting.

The Gum radar gun (44) was used for gathering the data related to testing the velocity of the soccer ball. The velocity of the shot, using both the right and left legs, was determined by the use of a radar gun in order to see if the resistance training program had an effect on the velocity of the shot.

Validity and Reliability

Validity of the Gum Radar Gun

The validity of the Gum Radar Gun was best explained by Dr. Niel Lark (49) from the Physics Department at the University of the Pacific. According to Dr. Lark, the difference between the emitted frequency and the measured reflected waves frequency is directly related to the speed of an object. By measuring the Doppler Shift in frequency between the emitted and returning pulse, the speed of an object can be measured. The reflected waves returning from an object calculate the velocity of the moving object and the velocity is shown on the digital readout.

Reliability of the Gum Radar Gun

The reliability of the Gum Radar Gun was tested through the use of a tuning fork. When a vibrating tuning fork is placed in front of the radar gun, a reading of 50 should appear on the digital readout. If a reading of 50 registers, the radar gun is considered to be in callibration and yielding a true reading (44).

Validity and Reliability of the Cybex II Isokinetic Dynometer

Moffroid and Whipple (56) tested the validity and the reliability of the Cybex II Isokinetic Dynometer. The callibration of the machine was done using weights placed on the lever arm. This was done isometrically at different angles and isokinetically at different speeds. The torque registrations showed high reliability ($r = 0.995$) and validity ($v = 0.999$).

The Collection of the Data

Eighteen members of the 1980 men's varsity soccer team at the University of the Pacific were used for the study. Five of the eighteen subjects were unable to attend the workout times because of scheduling problems. These individuals were assigned to the control group. The members of the control group were given a pre-test on the same day the experimental group was tested, a post-test following the eight week resistance training program the experimental group participated in, and a re-test ten days after the conclusion of the eight week resistance training program. The individuals who made up the control group were requested not to participate in any type of resistance training program for the eight week training period or the ten day rest period following the eight week training period. During the eight week training period, both the experimental group and the control group participated in daily soccer practice sessions.

Each subject was tested using six different muscle groups in each leg. The muscle groups tested were the flexors and extensors of the knee, the flexors and extensors of the hip, and the adductors and abductors of the leg.

The flexors and extensors of the knee were tested at the three following speeds: 60^{o}/second, 180^{o}/second, and 210^{o}/second. The flexors and extensors of the hip along with adductors and abductors of the leg were tested only at a speed of 30^{o}/second.

The flexors and extensors of the hip and the adductors and abductors of the leg were tested and exercised at a speed of 30^{o}/second for several reasons. First of all, the instruction manual for operating, testing, and function of the dynometer gave specific instructions as to the speed for testing specific muscle groups (25). According to the operation manual of the isokinetic dynometer, the flexors and extensors of the hip, and the adductors and abductors of the leg created a great deal of torque on the lever arm of the machine because of the leverage created and the angular positioning of the machine. Faster speeds could have easily damaged the machine.

Secondly, after discussing the experimental procedure with Jerry Solberg, R.P.T. (81), the physical therapist who advised the author, it was concluded that only one speed of testing was necessary.

Testing Procedures

Flexors and Extensors of the Knee

To test the flexors and extensors of the knee, each subject was seated in a chair with the force arm of the isokinetic dynometer lined up at the articulation of the tibia and femur. The lever arm of the machine ran parallel to the tibia and fibula along the lateral side of the leg. The strap attached to the lever arm was fastened two inches above the malleolus of the leg being tested. Another strap was attached across the femur of the leg being tested in order to isolate the flexors and extensors of the knee.

The angular velocity of the dynometer was initially set at 60 for the knee flexion and extension. Prior to the actual testing cycle, each subject was given three submaximal warm-ups at the setting of 60. Following this each subject was instructed to maximally extend and flex his leg for three trials. The results were recorded on a graph and the maximal knee extension and flexion was produced. The force, in foot pounds, exerted by the subject was recorded and graphed by the isokinetic dynometer.

This same testing procedure was used when testing subjects at settings of 180 and 210. The only difference occurred with the number of testing repetitions. Each subject was instructed to maximally extend and flex his leg for six trials. Six trials were used at the faster speeds in order to obtain a true maximal muscle contraction.

Flexors and Extensors of the Hip

To test the flexors and extensors of the hip, each subject lay on his back with the force arm of the isokinetic dynometer lined up at the articulation of the head of the femur and the acetabulum. The lever arm of the machine ran parallel to the femur along the lateral side of the leg. The strap attached to the lever arm was fastened four inches above the patella on the leg being tested. A second strap was fastened across the hips in order to isolate the extensors and flexors of the hip. A third strap was fastened across the chest of each subject to further control the body movement and isolate the extensors and flexors of the hip.

The angular velocity of the dynometer was set at 30 for the hip extension and flexion. Prior to the actual testing cycle, each subject was given three submaximal warm-ups at the setting of 30. Each subject was then instructed to maximally flex and extend the leg for six trials. The results were recorded on a graph and the maximal hip extension and flexion were produced. The force, in foot pounds, exerted by the subject, was recorded and graphed by the dynometer.

Adduction and Abduction of the Leg

To test hip adduction and abduction of the leg, each subject lay on his side with the force arm of the isokinetic dynometer lined up at the articulation of the head of the femur and the acetabulum. The lever arm of the machine ran parallel to the femur along the lateral side of the leg. The strap attached to the lever arm was fastened to the thigh two inches above the patella of the leg being tested. A second strap was fastened across the hips in order to isolate the adduction and abduction of the hip joint. A third strap was fastened across the chest of each subject to further control the body movement and isolate the adduction and abduction of the hip joint.

The angular velocity of the dynometer was set at 30 for leg adduction and abduction. Prior to the actual testing cycle, each subject was given three submaximal warm-ups at the setting of 30. Each subject was then instructed to maximally adduct and abduct the leg for six trials. The results were recorded on a graph and the maximal leg adduction and abduction were produced. The force, in foot pounds, exerted by the subjects was recorded and graphed by the dynometer.

Velocity of the Ball

To test the velocity at which the soccer ball traveled after being kicked, a standard test was used. The ball was placed approximately fifteen feet in front of the radar gun. The ball was inflated to twelve pounds. The same ball was used during the entire experiment in order to reduce the variables of different balls. Each subject took several warm-up kicks and then was tested three times for each leg.

The Training Period

The training period lasted eight weeks, during which time the subjects exercised three times weekly, with a day to rest between every workout session. Each subject was required to perform three sets of ten repetitions each, exercising all the muscle groups that were being examined.

The workout sessions for the quadricep and hamstring muscle groups were done on the orthotron. This was done in order to make the

Cybex II Isokinetic Dynometer available for exercising the flexors and extensors of the leg, and the abductors and adductors of the leg. While one group of subjects was using the Cybex II, the other group was using the Orthotron (61). This made it possible to exercise a greater number of people in a shorter period of time (see Appendix B). The machine was set at speeds of 60, 180, and 210 so that the individual could exercise at the same speed at which he was to be tested.

Treatment and Analysis of the Data

The data was collected using both the Cybex II Isokinetic Dynometer and the Gum Radar Gun. The results were analyzed using the Statistical Package for the Social Sciences (SPSS) system (59). The SPSS system provides the user with a comprehensive set of procedures for data transformation and file manipulation.

For this study, the mean, the standard error, the t ratio, and the probability of t were computed in order to determine results from the raw data. The .05 level of significance was chosen for all statistical analyses.

Chapter 4

RESULTS

Table 1 shows the original strength difference between the dominant and nondominant legs of eighteen University of the Pacific (UOP) male soccer players in six muscle groups at differing speeds of contraction. The results indicate that only one muscle group showed a significant difference in strength between the dominant leg and the nondominant legs. The adductors of the nondominant leg were found to be significantly stronger than the adductors of the dominant leg.

The mean score of the dominant leg was 115.33, while the mean score of the nondominant leg was 128.00. The t score for adduction of the dominant and nondominant legs was 2.44. Therefore, the main hypothesis which stated that there would be no significant strength difference between the mirror muscles of the six muscle groups in the dominant and nondominant legs of UOP male soccer players at differing contraction speeds was rejected.

Table 2 shows the strength difference between the pre-test and the post-test of the dominant leg of the experimental group in six muscle groups at differing speeds of contraction. The results show a significant increase in strength in the quadricep muscle group at the two speeds of 180^{0}/second and 210^{0}/second following an eight week strength training period. The pre-test mean score of the quadricep muscle group of the dominant leg at a speed of 180^{0}/second was 98.38, while the post-test mean score of the quadricep muscle group of the dominant leg at a speed

Table 1

Results of the t Ratio Test on Original Strength Between the Dominant and Nondominant Legs of UOP Male Soccer Players

		Dominant Leg		Nondominant Leg			
Muscle Group and Speed of Contraction	n	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep:							
60	18	158.56	6.24	158.94	5.42	0.12	0.91
180	18	95.22	3.38	95.94	4.10	0.32	0.75
210	18	87.56	3.25	86.39	3.52	0.66	0.52
Hamstring:							
60	18	110.22	5.68	110.50	5.92	0.08	0.94
180	18	77.67	3.64	77.44	4.65	0.08	0.94
210	18	71.61	3.23	72.00	3.61	0.15	0.88
Flexion	18	119.56	6.35	120.94	5.07	0.21	0.83
Extension	18	165.56	8.28	173.67	12.10	0.95	0.36
Adduction	18	115.33	5.12	128.00	5.31	2.44*	0.03
Abduction	18	87.72	3.40	91.78	3.40	1.04	0.31

*The t ratio required for 17 degrees of freedom at the .05 level was 2.11.

Table 2

Results of the t Ratio Test Between the Pre-test and the Post-test of the Dominant Leg for the Experimental Group

Muscle Group and Speed of Contraction	n	Pre-test $\overline{X}$ in ft. lbs.	Pre-test Standard Error of $\overline{X}$	Post-test $\overline{X}$ in ft. lbs.	Post-test Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep:							
60	13	162.46	7.47	165.15	7.38	0.53	0.61
180	13	98.38	4.15	113.77	6.53	3.11*	0.01
210	13	89.69	3.95	101.08	4.66	3.07*	0.01
Hamstring:							
60	13	117.08	5.65	115.38	5.41	0.33	0.75
180	13	81.69	4.08	89.61	3.89	1.65	0.13
210	13	73.61	3.80	81.38	3.65	1.73	0.11
Flexion	13	121.92	8.62	117.23	7.59	0.48	0.64
Extension	13	166.69	10.30	158.61	11.54	0.50	0.63
Adduction	13	120.54	6.49	123.38	5.41	0.49	0.63
Abduction	13	88.69	4.35	91.00	3.66	0.62	0.55

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18.

of 180^{0}/second was 113.77. The t score for the quadricep strength gain between the pre-test and the post-test at a speed of 180^{0}/second was 3.11, which proved to be significant at the .05 level.

The pre-test mean score of the quadricep muscle group of the dominant leg at a speed of 210^{0}/second was 89.69, while the post-test mean score of the quadricep muscle group of the dominant leg at a speed of 210^{0}/second was 101.08. The t score for the quadricep strength gain between the pre-test and the post-test at a speed of 210^{0}/second was 3.07, which also proved to be significant at the .05 level. Therefore, the hypothesis which stated there would be no significant change in strength in any of six muscle groups of the dominant leg following an eight week training program was rejected for the experimental group.

Table 3 shows the strength difference between the pre-test and the post-test of the dominant leg of the control group, using UOP male soccer players in six muscle groups at differing speeds of contraction. The results showed that none of the muscle groups yielded a significant t score at the .05 level, but it should be noted that the quadricep muscle group at a speed of 210^{0}/second was significant at the .08 level when comparing the pre-test and the post-test of the dominant leg. The pre-test mean score of the quadricep muscle group of the dominant leg at a speed of 210^{0}/second was 82.00, while the post-test mean score of the quadricep muscle group of the dominant leg at a speed of 210^{0}/second was 86.00. The t score for the quadricep strength gain between the pre-test and the post-test at a speed of 210^{0}/second was 2.39. Since no significant difference was found, the hypothesis which stated that there would be no significant change in strength in any of six muscle

Table 3

Results of the t Ratio Test Between the Pre-test and the Post-test of the Dominant Leg of the Control Group

Muscle Group and Speed of Contraction	n	Pre-test $\bar{X}$ in ft. lbs.	Pre-test Standard Error of $\bar{X}$	Post-test $\bar{X}$ in ft. lbs.	Post-test Standard Error of $\bar{X}$	t score	Prob. of t
Quadricep							
60	5	148.40	11.16	147.60	12.81	0.24	0.82
180	5	87.00	4.17	87.20	4.63	0.10	0.93
210	5	82.00	5.40	86.00	6.29	2.39	0.08
Hamstring							
60	5	92.40	11.65	94.00	11.68	0.78	0.48
180	5	67.20	5.89	60.00	5.62	0.46	0.67
210	5	66.40	6.11	67.20	8.40	0.23	0.83
Flexion	5	113.40	5.04	122.00	7.04	1.30	0.26
Extension	5	162.60	14.80	158.40	17.97	0.52	0.63
Adduction	5	101.80	3.01	106.80	3.38	1.86	0.14
Abduction	5	85.20	5.16	83.60	1.94	0.81	0.46

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

groups of the dominant leg following an eight week training program was accepted for the control group.

Table 4 shows the strength difference between the pre-test and the post-test of the nondominant leg of the experimental group in six muscle groups at differing speeds of contraction. The results showed a significant increase in strength of the quadricep muscle group at speeds of 180^{0}/second and 210^{0}/second, the hamstring muscle group at the speed of 210^{0}/second, and a significant strength loss for leg adduction.

The pre-test mean score of the quadricep muscle group of the non-dominant leg at a speed of 180^{0}/second was 99.46 while the post-test mean score of the quadricep muscle group of the nondominant leg at a speed of 180^{0}/second was 112.45. The t score for the quadricep strength gain between the pre-test and the post-test at a speed of 180^{0}/second was 4.76, which proved to be significant at the .05 level.

The pre-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210^{0}/second was 89.00, while the post-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210^{0}/second was 99.08. The t score for the quadricep strength gain between the pre-test and the post-test at a speed of 210^{0}/second was 3.35, which proved to be significant at the .05 level.

The pre-test mean score of the hamstring muscle group of the nondominant leg at a speed of 210^{0}/second was 74.77, while the post-test mean score of the hamstring muscle group of the nondominant leg at a speed of 210^{0}/second was 86.15. The t score for the hamstring strength gain between the pre-test and the post-test at a speed of 210^{0}/second was 2.75, which proved to be significant at the .05 level.

Table 4

Results of the t Ratio Test Between the Pre-test and the Post-test of the Nondominant Leg of the Experimental Group

		Pre-test		Post-test			
Muscle Group and Speed of Contraction	n	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep:							
60	13	162.31	6.23	169.38	7.53	1.38	0.19
180	13	99.46	4.75	112.15	4.71	4.76*	0.01
210	13	89.00	4.13	99.08	3.61	3.35*	0.01
Hamstring							
60	13	115.31	5.12	116.61	5.64	0.22	0.83
180	13	83.08	5.20	93.08	3.75	1.94	0.08
210	13	74.77	4.11	86.15	3.47	2.75*	0.02
Flexion	13	127.15	5.88	122.15	9.80	0.49	0.63
Extension	13	175.23	16.25	165.46	10.13	0.58	0.57
Adduction	13	130.23	6.27	115.31	5.17	2.81*	0.02
Abduction	13	92.77	4.38	85.23	3.32	1.45	0.17

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18.

The pre-test mean score of the leg adductors of the nondominant leg was 130.23 while the post-test mean score of the leg adductors of the nondominant leg was 115.31. The t score for the leg adduction strength loss between the pre-test and the post-test was 2.81, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of six muscle groups of the nondominant leg following an eight week training program was rejected for the experimental group.

Table 5 shows the strength difference between the pre-test and the post-test of the nondominant leg of the control group in six muscle groups at differing speeds of contraction. The results showed a significant increase in strength of the hamstring muscle group at a speed of 210°/second. The pre-test mean score of the hamstring muscle group of the nondominant leg at a speed of 210°/second was 64.80, while the post-test mean score of the hamstring muscle group of the nondominant leg at a speed of 210°/second was 68.00. The t score for the hamstring strength gain between the pre-test and the post-test at a speed of 210°/second was 3.14, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of six muscle groups of the nondominant leg following an eight week training program was rejected for the control group.

Table 6 shows the strength difference between the post-test and the re-test of the dominant leg of the experimental group in six muscle groups at differing speeds of contraction. The results showed that none of the muscle groups yielded significant t scores at the .05

Table 5

Results of the t Ratio Test Between the Pre-test and the Post-test for the Nondominant Leg of the Control Group

Muscle Group and Speed of Contraction	n	Pre-test $\bar{X}$ in ft. lbs.	Pre-test Standard Error of $\bar{X}$	Post-test $\bar{X}$ in ft. lbs	Post-test Standard Error of $\bar{X}$	t score	Prob. of t
Quadricep							
60	5	150.20	10.96	149.60	12.35	0.06	0.95
180	5	86.80	7.22	80.00	5.69	1.27	0.27
210	5	79.60	6.40	78.80	5.75	0.53	0.62
Hamstring							
60	5	98.00	16.67	92.80	13.35	1.32	0.26
180	5	62.80	6.71	66.00	6.87	2.14	0.10
210	5	64.80	7.06	68.00	6.90	3.14*	0.03
Flexion	5	104.80	5.75	108.40	7.70	1.13	0.32
Extension	5	169.60	13.20	169.60	16.06	0.00	1.00
Adduction	5	122.20	10.60	118.40	11.90	0.81	0.46
Abduction	5	89.20	4.96	85.60	3.71	0.74	0.50

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

Table 6

Results of the t Ratio Test Between the Post-test and the Re-test of the Dominant Leg of the Experimental Group

		Post-test		Re-test			
Muscle Group and Speed of Contraction	n	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	13	165.15	7.38	164.00	8.55	0.15	0.88
180	13	113.77	6.53	114.92	8.80	0.17	0.86
210	13	101.08	4.66	100.46	5.48	0.19	0.85
Hamstring							
60	13	115.38	5.41	124.61	6.04	1.72	0.11
180	13	89.61	3.89	96.31	7.13	1.31	0.21
210	13	81.38	3.65	86.15	5.25	1.43	0.18
Flexion	13	117.23	7.59	121.85	10.48	0.57	0.58
Extension	13	158.61	11.54	154.61	12.11	0.48	0.64
Adduction	13	123.38	5.41	132.31	9.72	0.86	0.41
Abduction	13	91.00	3.66	96.15	4.23	1.31	0.21

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18

level of significance. Therefore, the hypothesis which stated that there would be no significant change in strength of the six muscle groups of the dominant leg after a ten day rest period that followed the conclusion of an eight week training program was accepted for the experimental group.

Table 7 shows the strength difference between the post-test and the re-test of the dominant leg of the control group in six muscle groups at differing speeds of contraction. The results showed a significant loss in strength in the quadricep muscle group at a speed of 180°/second and a significant gain of strength in leg abduction.

The post-test mean score of the quadricep muscle group of the dominant leg at a speed of 180°/second was 87.20, while the re-test mean score of the quadricep muscle group of the dominant leg at a speed of 180°/second was 82.40. The t score for quadricep strength loss between the post-test and the re-test at a speed of 180°/second was 2.95, which proved to be significant at the .05 level.

The post-test mean score of the leg abductors of the dominant leg was 83.60, while the re-test mean score of the leg abductors of the dominant leg was 87.60. The t score for the leg abduction strength gain was 3.65, which also proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength of the six muscle groups of the dominant leg after the ten day rest period that follows the conclusion of the eight week training program was rejected for the control group.

Table 8 shows the strength difference between the post-test and the re-test of the nondominant leg of the experimental group in six

Table 7

Results of the t Ratio Test Between the Post-test and the Re-test of the Dominant Leg of the Control Group

Muscle Group and Speed of Contraction	n	Post-test $\overline{X}$ in ft. lbs.	Post-test Standard Error of $\overline{X}$	Re-test $\overline{X}$ in ft. lbs.	Re-test Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	5	147.60	12.81	150.00	13.30	2.06	0.11
180	5	87.20	4.63	82.40	5.04	2.95*	0.04
210	5	86.00	6.29	84.40	6.24	1.37	0.24
Hamstring							
60	5	94.00	11.68	95.60	12.62	0.72	0.51
180	5	68.00	5.62	68.40	4.83	0.34	0.75
210	5	67.20	8.40	68.40	6.85	0.31	0.77
Flexion	5	122.00	7.04	112.00	5.69	1.23	0.29
Extension	5	158.40	17.97	167.60	14.98	1.65	0.17
Adduction	5	106.80	3.38	108.00	3.29	0.39	0.72
Abduction	5	83.60	1.94	87.60	2.23	3.65*	0.02

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

Table 8

Results of the t Ratio Test Between the Post-test and the Re-test of the Nondominant Leg of the Experimental Group

Muscle Group and Speed of Contraction	n	Post-test $\overline{X}$ in ft. lbs.	Post-test Standard Error of $\overline{X}$	Re-test $\overline{X}$ in ft. lbs.	Re-test Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	13	169.38	7.53	160.92	9.18	1.17	0.26
180	13	112.15	4.71	118.00	8.66	0.91	0.38
210	13	99.08	3.61	100.61	5.65	0.38	0.71
Hamstring							
60	13	116.61	5.64	129.69	8.20	1.88	0.09
180	13	93.08	3.75	98.15	6.67	0.97	0.35
210	13	86.15	3.97	90.77	5.60	1.23	0.24
Flexion	13	122.15	9.80	121.08	9.54	0.10	0.92
Extension	13	165.46	10.13	152.92	10.01	1.67	0.12
Adduction	13	115.31	5.17	131.54	10.40	1.66	0.12
Abduction	13	85.23	3.32	96.61	4.65	2.20*	0.05

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18.

muscle groups at differing speeds of contraction. The results showed a significant gain in strength in the leg abductors. The post-test mean score of the leg abductors of the nondominant leg was 85.23, while the re-test mean score of the leg abductors of the nondominant leg was 96.61. The t score for the leg abduction strength gain was 2.20, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of the six muscle groups of the nondominant leg after the ten day rest period that follows the conclusion of the eight week training program was rejected for the experimental group.

Table 9 shows the strength difference between the post-test and the re-test of the nondominant leg of the control group in six muscle groups at differing speeds of contraction. The results showed a significant gain in strength of the quadricep muscle group at a speed of 210°/second and a significant gain in strength of the hamstring muscle group at a speed of 60°/second.

The post-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210°/second was 78.80, while the re-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210°/second was 82.40. The t score for the quadricep strength gain between the post-test and the re-test at a speed of 210°/second was 3.09, which proved to be significant at the .05 level.

The post-test mean score of the hamstring muscle group of the nondominant leg at a speed of 60°/second was 92.80, while the re-test mean score of the hamstring muscle group of the nondominant leg at a speed of 60°/second was 96.00. The t score for the hamstring strength gain

Table 9

Results of the t Ratio Test Between the Post-test and the Re-test of the Nondominant Leg of the Control Group

Muscle Group and Speed of Contraction	n	Post-test $\overline{X}$ in ft. lbs.	Post-test Standard Error of $\overline{X}$	Re-test $\overline{X}$ in ft. lbs.	Re-test Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	5	149.60	12.35	143.60	12.09	0.80	0.47
180	5	80.00	5.69	82.40	5.27	1.18	0.30
210	5	78.80	5.75	82.40	6.05	3.09*	0.04
Hamstring							
60	5	92.80	13.35	96.00	12.65	3.14*	0.03
180	5	66.00	6.87	66.00	5.76	0.00	1.00
210	5	68.00	6.90	64.40	8.18	1.69	0.17
Flexion	5	108.40	7.70	111.20	5.46	0.78	0.48
Extension	5	169.60	16.61	169.20	15.65	0.13	0.90
Adduction	5	118.40	11.09	118.40	7.57	0.00	1.00
Abduction	5	85.60	3.70	88.80	3.77	0.66	0.54

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

between the post-test and the re-test at a speed of 60^{o}/second was 3.14, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of the six muscle groups of the nondominant leg after the ten day rest period that follows the conclusion of the eight week training program was rejected for the control group.

Table 10 shows the strength difference between the pre-test and the re-test of the dominant leg of the experimental group in six muscle groups at differing speeds of contraction. The results showed a significant gain in strength in both the quadricep and hamstring muscle groups, each at two different speeds.

The pre-test mean score of the quadricep muscle group of the dominant leg at a speed of 180^{o}/second was 98.38, while the re-test mean score of the quadricep muscle group of the nondominant leg at a speed of 180^{o}/second was 114.92. The t score for the quadricep strength gain between the pre-test and the re-test at a speed of 180^{o}/second was 2.39, which proved to be significant at the .05 level.

The pre-test mean score of the quadricep muscle group of the dominant leg at a speed of 210^{o}/second was 89.69, while the re-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210^{o}/second was 100.46. The t score for the quadricep strength gain between the pre-test and the re-test of the dominant leg at a speed of 210^{o}/second was 2.55, which also proved to be significant at the .05 level.

The pre-test mean score of the hamstring muscle group of the dominant leg at a speed of 180^{o}/second was 81.69, while the re-test mean score of the hamstring muscle group of the dominant leg at a speed of

Table 10

Results of the t Ratio Test Between the Pre-test and the Re-test of the Dominant Leg of the Experimental Group

Muscle Group and Speed of Contraction	n	Pre-test $\bar{X}$ in ft. lbs.	Pre-test Standard Error of $\bar{X}$	Re-test $\bar{X}$ in ft. lbs.	Re-test Standard Error of $\bar{X}$	t score	Prob. of t
Quadricep							
60	13	162.46	7.47	164.00	8.55	0.23	0.82
180	13	98.38	4.15	114.92	8.80	2.39*	0.03
210	13	89.69	3.95	100.46	5.48	2.55*	0.03
Hamstring							
60	13	117.08	5.65	124.61	6.04	1.33	0.21
180	13	81.69	4.08	96.31	7.13	2.33*	0.04
210	13	89.00	4.13	100.61	5.65	2.27*	0.04
Flexion	13	121.92	8.61	121.84	10.47	0.01	0.99
Extension	13	166.69	10.30	154.61	12.11	0.89	0.39
Adduction	13	120.54	6.49	132.31	9.72	1.08	0.30
Abduction	13	88.69	4.35	96.15	4.23	1.38	0.19

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18.

180^{0}/second was 96.31. The t score for the hamstring strength gain between the pre-test and the re-test of the dominant leg at a speed of 180^{0}/second was 2.33 which also proved to be significant at the .05 level.

The pre-test mean score of the hamstring muscle group of the dominant leg at a speed of 210^{0}/second was 89.00, while the re-test mean score of the hamstring muscle group of the dominant leg at a speed of 210^{0}/second was 100.61. The t score for the hamstring strength gain between the pre-test and the re-test of the dominant leg at a speed of 210^{0}/second was 2.27 which also proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of the six muscle groups of the dominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program was accepted for the control group.

Table 11 shows the strength difference between the pre-test and the re-test of the dominant leg of the control group in six muscle groups at differing speeds of contraction. The results showed that none of the muscle groups yielded significant t scores at the .05 level, but it should be noted that the leg adductors were significant at the .06 level when comparing the pre-test to the re-test of the dominant leg. The pre-test mean score in leg adductors of the dominant leg was 101.80, while the re-test mean score in leg adductors of the dominant leg was 108.00. The t score for the leg adductors strength gain was 2.52. Since no significant difference was found, the hypothesis which stated that there would be no significant change in strength in any of the six muscle groups of the dominant leg when comparing the original test scores

Table 11

Results of the t Ratio Test Between the Pre-test and the Re-test
of the Dominant Leg of the Control Group

Muscle Group and Speed of Contraction	n	Pre-test $\overline{X}$ in ft. lbs.	Pre-test Standard Error of $\overline{X}$	Re-test $\overline{X}$ in ft. lbs.	Re-test Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	5	148.40	11.66	150.00	13.30	0.51	0.64
180	5	87.00	4.17	82.40	5.04	2.03	0.11
210	5	82.00	5.40	84.40	6.24	1.81	0.14
Hamstring							
60	5	92.40	11.65	95.60	12.62	1.55	0.20
180	5	67.20	5.89	68.40	4.83	0.58	0.59
210	5	66.40	6.11	68.40	6.85	1.12	0.33
Flexion	5	113.40	5.04	112.00	5.69	0.72	0.51
Extension	5	162.60	14.80	167.60	14.98	1.98	0.12
Adduction	5	101.80	3.01	108.00	3.29	2.52	0.06
Abduction	5	85.20	5.16	87.60	2.23	0.77	0.48

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program was accepted for the control group.

Table 12 shows the strength difference between the pre-test and the re-test of the nondominant leg of the experimental group in six muscle groups at differing speeds of contraction. The results showed a significant gain in strength in the quadricep muscle group at the speeds of 180^{0}/second and 210^{0}/second, and a significant gain in strength of the hamstring muscle group at the speed of 180^{0}/second.

The pre-test mean score of the quadricep muscle group of the nondominant leg at a speed of 180^{0}/second was 99.46, while the re-test mean score of the quadricep muscle group of the nondominant leg at a speed of 180^{0}/second was 118.00. The t score for the quadricep strength gain between the pre-test and the re-test at a speed of 180^{0}/second was 2.57, which proved to be significant at the .05 level.

The pre-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210^{0}/second was 89.00, while the re-test mean score of the quadricep muscle group of the nondominant leg at a speed of 210^{0}/second was 100.61. The t score for the quadricep strength gain between the pre-test and the re-test at a speed of 210^{0}/second was 2.27, which also proved to be significant at the .05 level.

The pre-test mean score of the hamstring muscle group of the nondominant leg at a speed of 180^{0}/second was 83.08, while the re-test mean score of the hamstring muscle group of the nondominant leg at a speed of 180^{0}/second was 98.15. The t score for the hamstring strength gain between the pre-test and the re-test at a speed of 180^{0}/second

Table 12

Results of the t Ratio Test Between the Pre-test and the Re-test of the Nondominant Leg of the Experimental Group

		Pre-test		Re-test			
Muscle Group and Speed of Contraction	n	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep:							
60	13	162.31	6.23	160.92	9.18	0.16	0.87
180	13	99.46	4.75	118.00	8.66	2.57*	0.02
210	13	89.00	4.13	100.61	5.65	2.27*	0.04
Hamstring							
60	13	115.31	5.12	129.69	8.20	2.01	0.07
180	13	83.08	5.20	98.15	6.67	2.87*	0.01
210	13	73.61	3.80	86.15	5.25	2.08	0.06
Flexion	13	127.15	5.88	121.08	9.54	0.71	0.49
Extension	13	175.23	16.25	152.92	10.01	1.59	0.14
Adduction	13	130.23	6.27	131.54	10.40	0.14	0.89
Abduction	13	92.77	4.38	96.61	4.65	0.72	0.48

*The t ratio required for 12 degrees of freedom at the .05 level was 2.18.

was 2.87, which was significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in strength in any of the six muscle groups of the nondominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program was rejected for the experimental group.

It should be noted that even though the hamstring muscle groups at speeds of 60^0/second and 210^0/second did not yield significant scores at the .05 level, the hamstring muscle group at a speed of 60^0/second yielded a significant score at the .07 level, and the hamstring muscle group at a speed of 210^0/second yielded a significant score at the .06 level.

Table 13 shows the strength difference between the pre-test and the re-test of the nondominant leg of the control group in six muscle groups at differing speeds of contraction. The results showed that none of the muscle groups yielded significant t scores at the .05 level of significance. Therefore, the hypothesis which stated that there would be no significant change in strenth in any of the six muscle groups of the nondominant leg when comparing the original test scores prior to the training program to the test scores taken after the ten day rest period following the conclusion of the training program, was accepted for the control group.

Table 14 shows the results of the t ratio test between the pre-test and the post-test on ball velocity when kicked with the dominant leg of the experimental group. The results showed a significant gain in velocity of a kicked soccer ball as a result of the training program.

Table 13

Results of the t Ratio Test Between the Pre-test and the Re-test of the Nondominant Leg of the Control Group

		Pre-test		Re-test			
Muscle Group and Speed of Contraction	n	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	$\overline{X}$ in ft. lbs.	Standard Error of $\overline{X}$	t score	Prob. of t
Quadricep							
60	5	150.20	10.96	143.60	12.09	1.28	0.27
180	5	86.80	7.22	82.40	5.27	0.99	0.38
210	5	79.60	6.40	82.40	6.05	1.51	0.21
Hamstring							
60	5	98.0	16.67	96.00	12.65	0.44	0.68
180	5	62.80	6.71	66.00	5.76	1.55	0.19
210	5	64.80	7.06	64.40	8.18	0.15	0.89
Flexion	5	104.80	5.75	111.20	5.46	1.78	0.15
Extension	5	169.60	13.20	169.20	15.65	0.11	0.91
Adduction	5	122.20	10.60	118.40	7.57	0.84	0.45
Abduction	5	89.20	4.96	88.80	3.77	0.15	0.89

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

Table 14

Results of the t Ratio Test on Ball Velocity Between the Pre-test and Post-test when Kicked with the Dominant Leg of the Experimental Group

		Pre-test		Post-test			
Leg	n	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	t score	Prob. of t
Dominant	13	44.69	1.59	53.46	1.27	8.49*	0.00

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

The pre-test mean score of the ball velocity of the dominant leg was 44.69, while the post-test mean score of the ball velocity of the dominant leg was 53.46. The t score for the ball velocity increase between the pre-test and the post-test was 8.49, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in velocity of a soccer ball kicked with the dominant leg following an eight week training program was rejected for the experimental group.

Table 15 shows the results of the t ratio test between the pre-test and the post-test on ball velocity when kicked with the dominant leg of the control group. The results showed a significant gain in velocity of a kicked soccer ball as a result of the training program.

The pre-test mean score of the ball velocity of the dominant leg was 44.60, while the post-test mean score of the ball velocity of the dominant leg was 51.40. The t score for the ball velocity increase between the pre-test and the post-test was 9.25, which proved to be significant at the .05 level. Therefore the hypothesis which stated that there would be no significant change in velocity of a kicked soccer ball with the dominant leg following an eight week training program was rejected for the control group.

Table 16 shows the results of the t ratio test between the pre-test and the post-test on ball velocity when kicked with the nondominant leg of the experimental group. The results showed a significant gain in velocity of a kicked soccer ball as a result of the training program.

The pre-test mean score of the ball velocity of the nondominant leg was 42.69, while the post-test mean score of the ball velocity of the

Table 15

Results of the t Ratio Test on Ball Velocity Between the Pre-test and Post-test when Kicked with the Dominant Leg of the Control Group

		Pre-test		Post-test			
Leg	n	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	t score	Prob. of t
Dominant	5	44.60	2.44	51.40	2.36	9.25*	0.00

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

Table 16

Results of the t Ratio Test on Ball Velocity Between the Pre-test and Post-test when Kicked with the Nondominant Leg of the Experimental Group

		Pre-test		Post-test			
Leg	n	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	t score	Prob. of t
Nondominant	13	42.69	1.86	52.08	1.33	6.44*	0.00

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

nondominant leg was 52.08. The t score for the ball velocity increase between the pre-test and the post-test was 6.44, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in velocity of a soccer ball kicked with the nondominant leg following an eight week training program was rejected for the experimental group.

Table 17 shows the results of the t ratio test between the pre-test and the post-test on ball velocity when kicked with the nondominant leg of the control group. The results showed a significant gain in velocity of a kicked soccer ball as a result of the training program.

The pre-test mean score of the ball velocity of the nondominant leg was 43.20 while the post-test mean score of the ball velocity of the nondominant leg was 50.80. The t score for the ball velocity increase between the pre-test and the post-test was 4.57, which proved to be significant at the .05 level. Therefore, the hypothesis which stated that there would be no significant change in velocity of a soccer ball kicked with the nondominant leg following an eight week training program was rejected for the control group.

Table 18 shows the ball velocity difference between the experimental group and the control group on the pre-test when using the dominant leg. The results show that there was no significant difference in the velocity of a kicked soccer ball between the experimental group and the control group. Therefore, the hypothesis which states that there would be no significant difference in ball velocity between the experimental group and the control group when kicked a soccer ball with the dominant leg was accepted.

Table 17

Results of the t Ratio Test on Ball Velocity Between the Pre-test and Post-test when Kicked with the Nondominant Leg of the Control Group

Leg	N	Pre-test $\overline{X}$ of MPH	Pre-test Standard Error of $\overline{X}$	Post-test $\overline{X}$ of MPH	Post-test Standard Error of $\overline{X}$	t score	Prob. of t
Nondominant	5	43.20	3.71	50.80	2.96	4.57*	0.01

*The t ratio required for 4 degrees of freedom at the .05 level was 2.78.

Table 18

Results of the t Ratio Test on Ball Velocity when Kicked with the Dominant Leg Comparing the Experimental Group and Control Group during the Pre-test

	Experimental Group			Control Group				
Leg	N	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	N	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	t score	Prob. of t
Dominant	13	44.69	1.59	5	44.60	2.44	0.03	0.98

Table 19 shows the ball velocity difference between the experimental group and the control group on the post-test, using the dominant leg. The results show that there was no significant difference in the velocity of a kicked soccer ball between the experimental group and the control group following an eight week resistance training program. Therefore, the hypothesis which stated that there would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the dominant leg following an eight week resistance training program was accepted.

Table 20 shows the ball velocity difference between the experimental group and the control group on the pre-test when using the non-dominant leg. The results show that there was no significant difference in the velocity of a kicked soccer ball between the experimental group and the control group. Therefore, the hypothesis which stated that there would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the nondominant leg was accepted.

Table 21 shows the ball velocity difference between the experimental group and the control group using the nondominant leg following an eight week resistance training program. The results show that there was no significant difference in the velocity of a kicked soccer ball between the experimental group and the control group following an eight week resistance training program. Therefore, the hypothesis which stated that there would be no significant difference in ball velocity between the experimental group and the control group when kicking a soccer ball with the nondominant leg following an eight week resistance training program was accepted.

Table 19

Results of the t Ratio Test on Ball Velocity when Kicked with the Dominant Leg Comparing the Experimental Group and Control Group during the Post-test

	Experimental Group			Control Group				
Leg	N	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	N	$\overline{X}$ of MPH	Standard Error of $\overline{X}$	t score	Prob. of t
Dominant	13	53.46	1.27	5	51.40	2.36	0.77	0.47

*The t ratio required at the .05 level was 2.11.

Table 20

Results of the t Ratio Test on Ball Velocity when Kicked with the Nondominant Leg Comparing the Experimental Group and Control Group during the Pre-test

	Experimental Group			Control Group				
Leg	N	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	N	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	t score	Prob. of t
Nondominant	13	42.69	1.85	5	43.20	3.71	0.12	0.91

Table 21

Results of the t Ratio Test on Ball Velocity when Kicked with the Nondominant Leg Comparing the Experimental Group and Control Group during the Post-test

	Experimental Group			Control Group				
Leg	N	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	N	$\bar{X}$ of MPH	Standard Error of $\bar{X}$	t score	Prob. of t
Nondominant	13	52.08	1.33	5	50.80	2.96	0.39	0.71

*The t ratio required at the .05 level was 2.11.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine if a significant strength difference existed among the mirror muscles of six muscle groups in the dominant and nondominant legs of male soccer players. Different contraction speeds were measured by the Cybex II Isokinetic Dynometer. In addition, several subproblems were established: (1) to determine if an eight week training program had an effect on strength in any of the six muscle groups; (2) to determine if an eight week training program had an effect on the velocity of a kicked soccer ball; and (3) to determine if a ten day rest period and the conclusion of the eight week training period had an effect on the strength in any of the six muscle groups.

The subjects for this investigation were 18 male, varsity soccer players from the UOP varsity soccer team. Thirteen of the subjects made up the experimental group, while the remaining five subjects made up the control group. The control group was selected by use of a random sampling technique.

The instruments used for the collection of the data were the Cybex II Isokinetic Dynometer (25), which was used to measure the strength of the different muscle groups, and the Gum Radar Gun (44), which was used to measure the velocity of a kicked soccer ball. The validity and reliability of the Cybex II Isokinetic Dynometer was tested and proven to be reliable at the 0.99 level and valid at the 0.99 level (54). The validity and reliability of the Gum Radar Gun was proven using different methods.

The collection of the data took place during the spring semester of the 1980-81 academic year. Each of the subjects used in the investigation was tested at the beginning of the spring semester using both the Cybex II Isokinetic Dynometer and the Gum Radar Gun. The experimental group then began their eight week resistance training program, while the control group received no resistance training program. At the end of the eight week training period, both the experimental group and the control group were re-tested using the Cybex II Isokinetic Dynometer and the Gum Radar Gun. Ten days after these tests were administered, the subjects were tested again on the Cybex II Isokinetic Dynometer.

The mean, standard error, t score, and probability of t were computed for each muscle group at the differing speeds of contraction. This statistical information was used in determining the significant differences in strength and changes in velocity of a kicked soccer ball.

Statistical significance at the .05 level was found in the following instances:

1. The leg adductors of the nondominant leg during the pre-test while examining the total sample.

2. The quadricep muscle group of the dominant leg at speeds of 180^{0}/second and 210^{0}/second when comparing the pre-test to the post-test for the experimental group.

3. The quadricep muscle group at speeds of 180^{0}/second and

210^{o}/second, the hamstring muscle group at the speed of 210^{o}/second, and the leg adductors of the nondominant leg when comparing the pre-test to the post-test for the experimental group.

4. The hamstring muscle group of the nondominant leg at the speed of 210^{o}/second when comparing the pre-test to the post-test for the control group.

5. The quadricep muscle group at the speed of 180^{o}/second and the leg abductors of the dominant leg when comparing the post-test to the re-test for the control group.

6. The leg abductors of the nondominant leg when comparing the post-test to the re-test for the experimental group.

7. The quadricep muscle group at the speed of 210^{o}/second and the hamstring muscle group at the speed of 60^{o}/second of the nondominant leg when comparing the post-test to the re-test for the control group.

8. The quadricep muscle group at speeds of 180^{o}/second and 210^{o}/second, and the hamstring muscle group at speeds of 180^{o}/second and 210^{o}/second of the dominant leg for the experimental group when comparing the pre-test to the re-test.

9. The quadricep muscle group at speeds of 180^{o}/second and 210^{o}/second, and the hamstring muscle group at the speed of 180^{o}/second of the nondominant leg for the experimental group when comparing the pre-test to the re-test.

10. The ball velocity using the dominant leg when comparing the pre-test to the post-test for the experimental group.

11. The ball velocity using the dominant leg when comparing the pre-test to the post-test for the control group.

12. The ball velocity using the nondominant leg when comparing the pre-test to the post-test for the experimental group.

13. The ball velocity using the nondominant leg when comparing the pre-test to the post-test for the control group.

No statistical differences were found in the remainder of muscle group comparisons.

No statistical differences for ball velocity between the pre- and post-test means for the experimental group when compared to the control group were found.

Conclusions

Based on the results of this study, the following conclusions seem warranted:

1. In the main problem of the study, muscular imbalance was examined. Of the six muscle groups studied, only the adductors of the nondominant leg were found to be significantly stronger than the adductors of the dominant leg. Even this difference was negated following the training program. Therefore, it becomes apparent that muscle imbalances are not a factor in the soccer players used in this study.

2. The methods of applying the resistance training were only partially successful. The majority of the strength gain occurred in the muscular contractions at faster speeds. Apparently, the procedures did not overload all the muscle groups sufficiently beyond that already imposed by practicing soccer.

3. The kicked ball velocity was apparently unaffected by the overload resistance training procedures applied in this study.

Recommendations

It is recommended that future studies be carried out that deal with exercising the muscle groups at faster speeds than 210^{o}/second.

It is recommended that future studies be carried out that deal with determining what muscle groups are specifically used when performing a soccer kick.

It is recommended that future studies be carried out that deal with the relationship of torque to increased shot velocity.

Discussion

According to Jesse (42-68), sports predispose an athlete to unilateral and unbalanced muscular development of the muscles of his body. In this study, however, significant differences in strength between the mirror muscle groups of the dominant and nondominant legs of soccer players were not found in the majority of the muscle groups. This would suggest that athletes performing skills which require unilateral muscular development naturally develop strength in the mirror muscle groups. When examining the dominant and nondominant legs of soccer players, both legs must be utilized and therefore ambi-function is achieved.

Significant improvement occurred mainly in the muscle groups exercising at faster speeds. This occurred in both the dominant and nondominant legs. This seems to reinforce previous research which showed that exercising at higher increased speeds will help to increase muscular strength (41, 51, 73, 85, 88).

It is believed that one limiting factor encountered could involve the speeds used on the Cybex II Isokinetic Dynometer (25). As reported by DeVries (27), strength gain is limited to the velocities at or below those used in training. It was shown that significant gains in strength could not be demonstrated when the velocity of contraction was greater than the speed at which the training occurred. Therefore, it is believed that training at increased limb speeds could have an effect on the increases of muscle strength and shot velocity.

Increases in shot velocity occurred in all the groups and categories tested when comparing the pre-test to the post-test. This would suggest that actual soccer practice has as much of an effect on shot velocity as the resistance training program as applied in this study.

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APPENDIX A

MUSCLES AND THEIR ACTION DURING THE SOCCER KICK

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Gluteus Maximus: Extends, laterally rotates, assists in adduction of the hip joint.

Pectineus, Adductor Magnus, Adductor Brevis, Adductor Longus, Gracilis: Adduct the hip joint. All but the Adductor Magnus flex the hip joint.

Piriformis, Quadratus Femoris, Obturator Internus, Obturator Externus, Gemellus Superior, Gemellus Inferior: Laterally rotate the hip joint. The Quadratus Femoris and the Obturator Externus may assist in adduction of the hip joint.

Gluteus Medius: Abducts the hip joint. The antior fibers medially rotate and may assist in flexion of the hip joint.

Gluteus Minimus: Abducts, medially rotates and may assist in flexion of the hip joint.

Tensor Fasciae Latae: Flexes, medially rotates and abducts the hip joint, and may assist in knee extension.

Sartorius: Flexes, laterally rotates and abducts the hip joint. Flexes and assists in medial rotation of the knee joint.

Psoas Major, Iliacus: With the origins fixed, the Illiopsoas flexes the hip joint by flexing the femur on the trunk. May assist in lateral rotation and abduction of the hip joint. With the insertion fixed, the Illiopsoas flexes the hip joint by flexing the trunk on the femur.

Rectus Femoris, Vastus Lateralis, Vastus Intermedius, Vastus Medialis: Extends the knee joint and the Rectus Femoris flexes the hip joint.

Biceps Femoris: Flex and laterally rotate the knee joint. Extends and assists in lateral rotation of the hip joint.

Semitendonosus, Semimembronosus: Flexes and medially rotates knee joint, extends and assists in medial rotation of the hip joint.

Popliteus: In non-weight-bearing, the Popliteus medially rotates the the tibia on the femur and flexes the knee joint. In weight-bearing, the Popliteus laterally rotates the femur on the tibia and flexes the knee joint.

<u>Gastrocnemius</u>, <u>Plantaris</u>: Planter flex the ankle joint and assist in flexion of the knee joint.

<u>Flexor Digitorum Longus</u>, <u>Peroneous Longus</u>, <u>Peroneous Brevis</u>, <u>Tibialus Posterior</u>: Assists in planter flexion of the ankle joint.

<u>Flexor Hallucis Longus</u>: Planter flexion of the ankle joint.

APPENDIX B

ORTHOTRON

ORTHOTRON

The Orthotron is an isolated-joint, reciprocal, isokinetic system manufactured by the Cybex Company. According to the instruction manual for the Orthotron, "Using Orthotron with Cybex's special S-H-D Tables for knee exercise provides research-proven ideal body positioning for both quadricep and hamstring strengthening" (25).

As with the isokinetic dynometer, the Orthotron provides resistance throughout the full range of the movement. It allows exercise at fast, functional speeds to develop higher levels of muscular power and endurance.

Individual dials for both directions of movement, knee flexion and extension, control the exercise speeds. Therefore the settings of 60^{o}/second, 180^{o}/second, and 210^{o}/second were all achieved while exercising with the Orthotron.